On Inflatable Drones for Flight Time Enhancement with Particular Reference to Spectator Aerostation

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In this note consideration is given to drones - and specially quadcopters, endowed with inflatable and controllable airbags filled with helium which is stored in small and replaceable cartridges. The goal is the a flight time enhancement due to the buoyancy provided by the inflated airbag. It is shown that by using an airbag with $\approx 20\%$ or thereabouts of the weight of the drone, the flight time could be increased ten-fold and then being very attractive for spectator aerostation. The idea seems with practical application for drones weighting less than 1 kilogram and using small helium replaceable cartridges in a similar fashion as used to inflate bike tires.

Keywords. *Drone, Quadcopters, Buoyancy, Flight time*

I. INTRODUCTION

Drones -and specially quadcopters, are on the rise with each passing year and more and more people are embracing the idea of owning such devices. However, one of the major handicap is theirs reduced flight time limited by the drone´s battery. Nowadays, the flight time of the drone although varies from model to model, however, it can be ranged from 12 minutes in the Yuneec Breeze to 25 minutes in the Yuneec Typhoon 4k, up to and up to 28 minutes for the DJI Phantom 4. The reduced flight time is an special issue for scientific activities such as geographic mapping or wildlife monitoring.

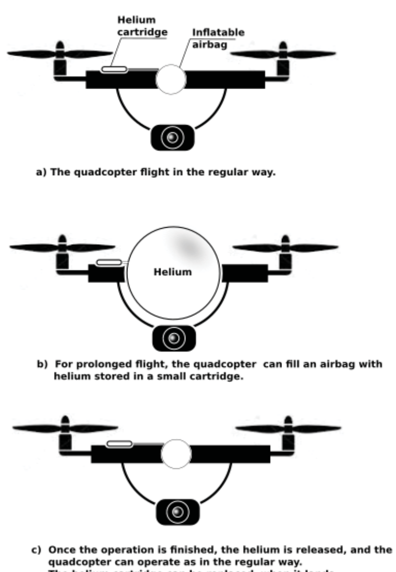

FIG. 1: A sketch for a possible inflatable quadcopter.

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• Statement of the core idea

The object of this work is a first assessment on the use of a drone and with particular reference in quadcopters but endowed with inflatable airbags filled with helium stored in small replaceable cartridges in a similar fashion as CO_2 cartridges are used to inflate bike tires. The airbag of the drone could be filled with the helium at any time and in a totally controllable way by using a simple valve between the cartridge and the airbag. The resulting buoyancy when the helium airbag is inflated translate into an apparent reduction of the mass of the drone and therefore increasing the flight time. In this preliminary work the basis of the idea is outlined.

To begin with, let us assume a simple quadcopter as depicted in Fig.1, which in addition, it has been endowed with a controllable inflatable airbag which, as aforementioned, can be inflated when is desired by just opening a control valve and can be equally deflated by using another simple relief valve and evacuating the helium into the atmosphere. The helium cartridge can be replaced or refilled after landing.

First, let us call the mass of the drone without airbag as m_o, and the mass of the airbag as m_b. The mass of the airbag can be divided into two terms. On one hand the mass from the material and on the other hand the mass of the helium filling it. However, if it is assumed that the thickness of the airbag is small enough in comparison with the diameter of the airbag, it is allowable to assume that the mass of the airbag is manly given by the mass of the helium. Thus, the the total mass of the drone m is given by

$$m = m_o + m_b \tag{1}$$

On the other hand, the resulting buoyancy when the airbag is filled with the helium (initially contained a high pressure in the small cartridge) is manifested as an apparent reduction of the mass of the drone in an amount given by

$$-m_b\left(\frac{\rho_{air}}{\rho_{he}}-1\right) \tag{2}$$

where ρ_{air} and ρ_{he} are the density of the air and helium, respectively. In this way, an effective or apparent mass of the drone $m*$ may be defined as

$$m* = m_o - m_b\left(\frac{\rho_{air}}{\rho_{he}}-2\right) \tag{3}$$

- **Flight time**

The time of sustentation, time of autonomy or flight time can easily be calculated as follows:
First, during sustentation, the thrust T must be equal than the weight of the drone, and then

$$T = m_o g \tag{4}$$

where g is the gravity acceleration. On the other hand, the relationship between power P and thrust is given by,

$$P = \frac{Tv}{2} \tag{5}$$

where v is the exhaust velocity from the engines or thrusters which is always the same no matter if it is used airbag or not providing that the same thrusters are used. The required energy ΔE for sustentation during a given time of flight t_{fo} is given by

$$\Delta E = Pt_{fo} \tag{6}$$

or by taking into account Eq.(4) and Eq.(5) yields

$$\Delta E = \frac{m_o g v}{2} t_{fo} \tag{7}$$

Now, with the same available energy, the increase of flight time of the inflatable drone is given by

$$t_f = t_{fo}\left[\frac{m*}{m_o}\right] \tag{8}$$

where t_{fo} is the flight time from a traditional drone without auxiliary inflatable airbag.
Inserting Eq.(3) into Eq.(8) one obtains

$$t_f = t_{fo}\left[\frac{1}{1-\frac{m_b}{m_o}\left(\frac{\rho_{air}}{\rho_{he}}-2\right)}\right] \tag{9}$$

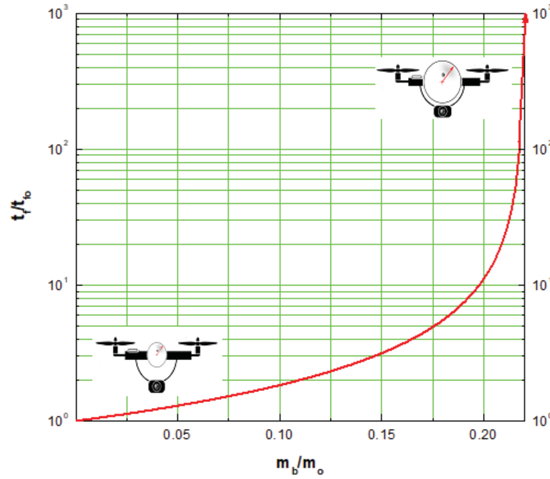

FIG. 2: Flight-time enhancement as function of the mass ratio between the airbag and the quadcopter.

- **Discussion**

Fig. 2 shows the increase of the flight time as function of the mass of the airbag-to- mass of the drone ratio. It is easy to see that, for instance, an airbag weighting around a 20% the mass of the drone the flight time can be increased up to a 10-fold, or which is the same, form the current 10-15 minutes of autonomy to 150 minutes of flight which is an attractive figure.

Nevertheless, this figure, although highly attractive must be put into context considering the practical availability of helium in the cartridge which is given mostly by the maximum pressure and dimensions of the cartridge.

If one use a cartridge as used to inflate tires, the the maximum pressure is just around 10 bars. So, assuming a practical cylindrical cartridge with a diameter, say, 3 cm and length 15 cm (easily transportable by a small drone) we will have a volume of the cartridge around 106 cm^3. The density at 1 bar and normal conditions of helium is around ≈ 0.18 gr/cm^3 or thereabouts, and thus we have in our cartridge with 10 bar a density of ≈ 1.8 gr/cm^3 or thereabouts. That give us a mass of helium contained inside the cartridge around 190 grams of helium. Therefore, if our drone weight around 5 times the weight of helium., i.e.., 950 grams, we have from Fig. 1 a magnification of its flight time a ten-fold. From this 950 grams we must to consider the weight of the cartridge, which if it is of similar material than the CO_2 cartridges used to inflate bike tires -which is around 8 grams per centimeter length of the cartridge, and therefore for our cartridge with 15 cm of length this will be around 120 grams. All in all, the total mass of the drone excluding the helium and the cartridge weight will be on 830 grams.

ACKNOWLEDGEMENTS

This research was supported by the Spanish Ministry of Economy and Competitiveness under fellowship grant Ramon y Cajal: RYC-2013-13459.